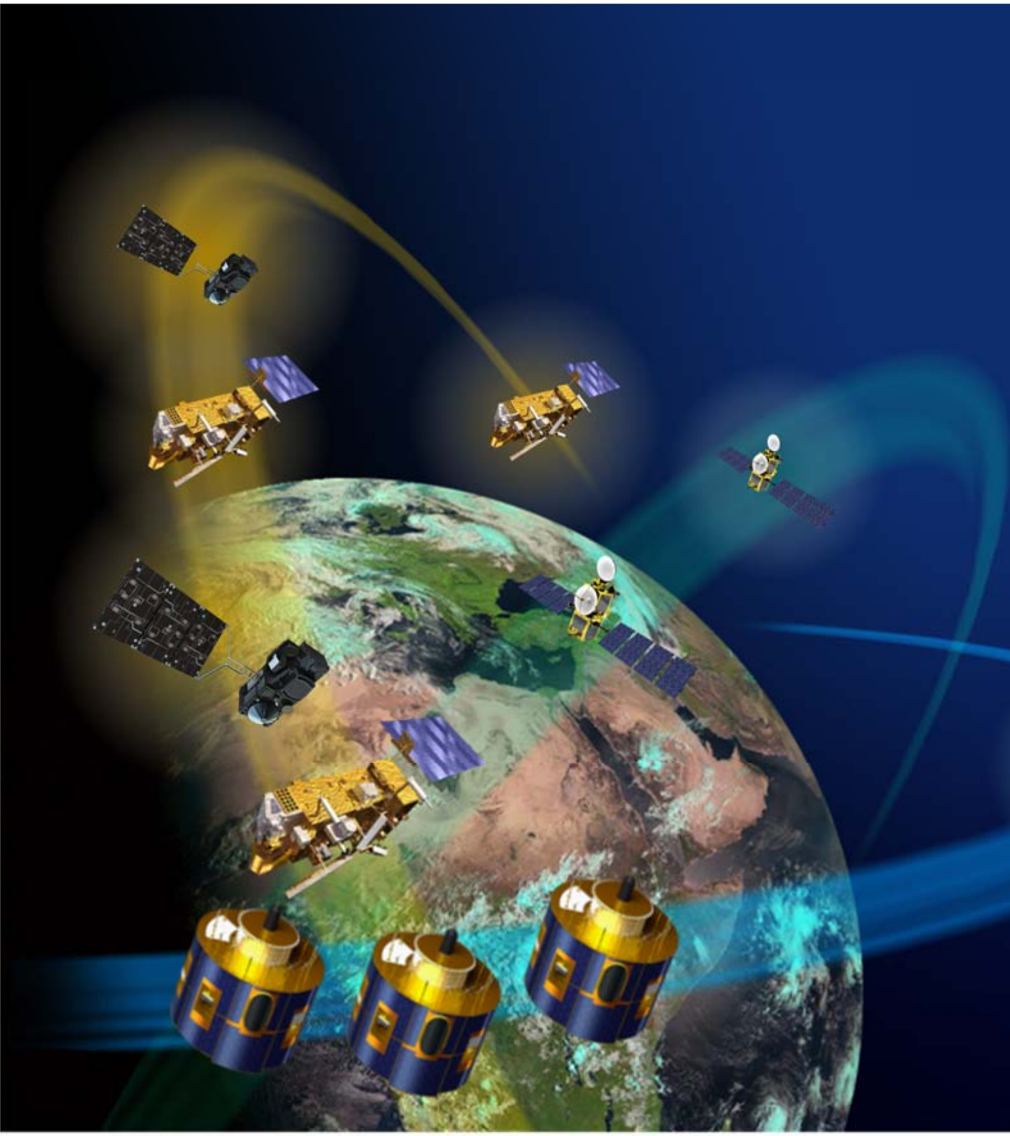
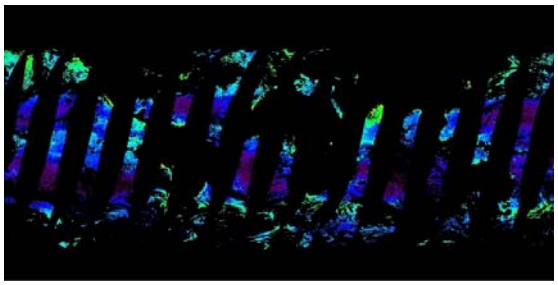
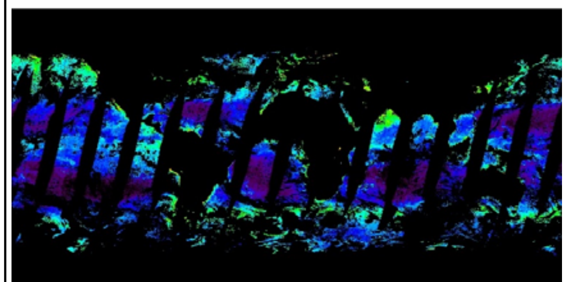
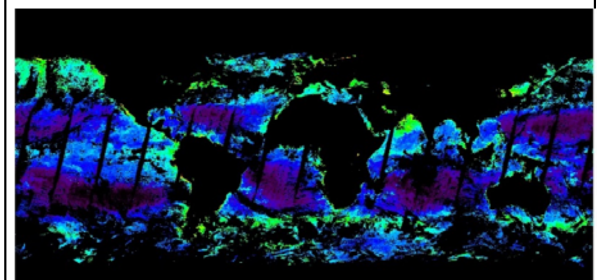
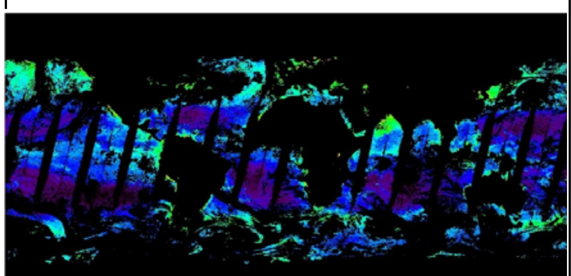
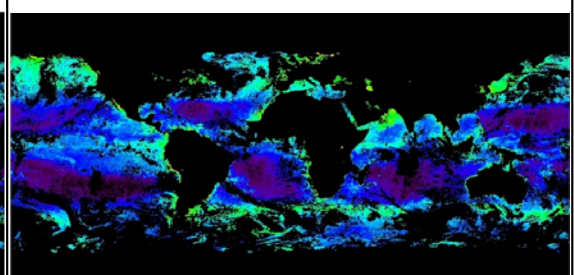
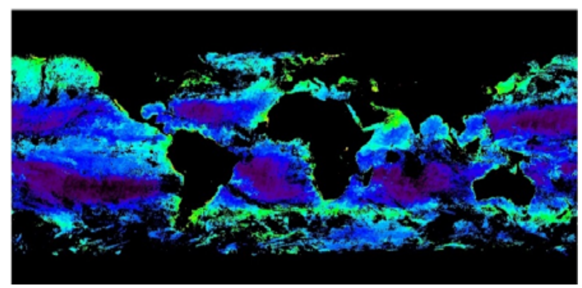


EUMETSAT

Emerging applications and science

ewa.kwiatkowska@eumetsat.int

Copernicus Sentinel-3A and -3B constellation is now operational

OLCI-A, 1-day coverage CHL_OC4ME	OLCI-A, 2-day coverage	OLCI-A, 3-day coverage
		
OLCI-A + OLCI-B, 1-day coverage	OLCI-A+OLCI-B, 2-day coverage	OLCI-A+OLCI-B, 3-day coverage
		

Sentinel-3 constellation status

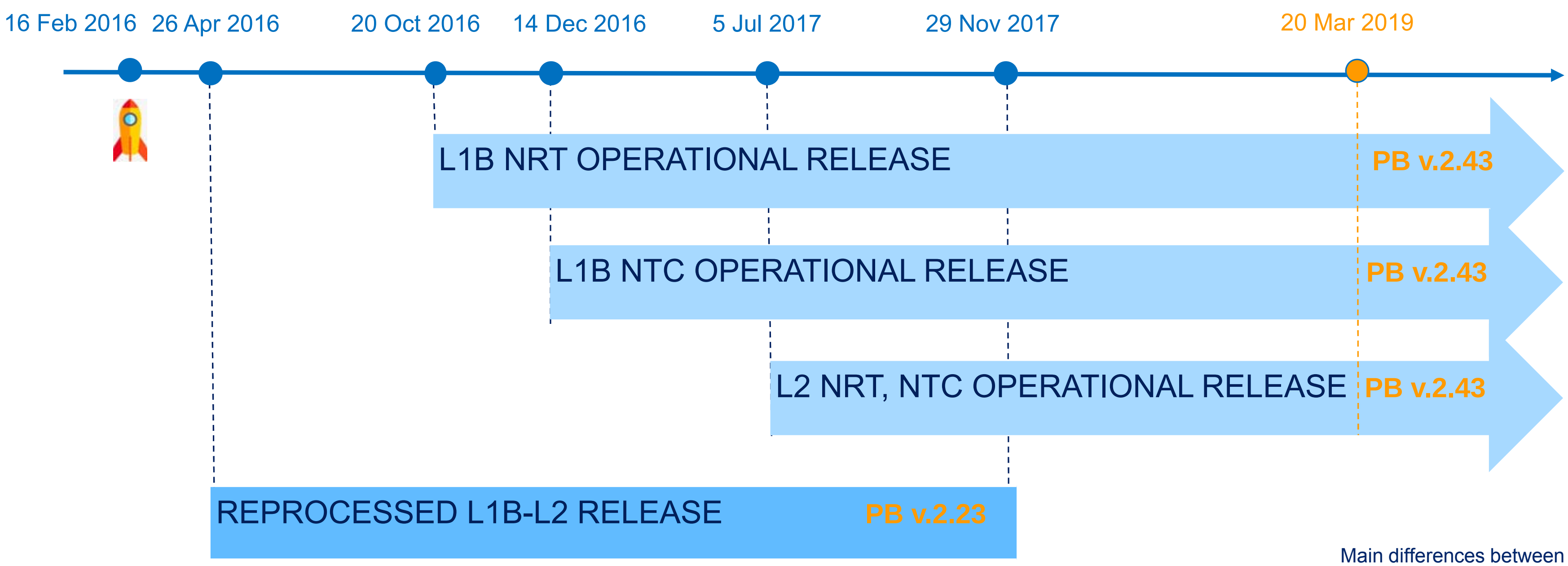
- Sentinel-3A launched on 16 February 2016, in routine operation since October 2017

- Its twin Sentinel-3B launched on 25 April 2018, in routine operation since March 2019

- Sentinel-3A and -3B tandem phase between 6 June and 16 October 2018:
  - ✓ Sentinel-3B flying 30 seconds ahead of Sentinel-3A on the same ground track
  - ✓ Observation of similar Ocean and Atmosphere by both satellites
  - ✓ Extremely valuable data:
    - ➢ Analysing differences between the missions (biases, trends…)
    - ➢ Improving instrument calibration and characterization
    - ➢ Improving knowledge of measurement uncertainties

- Constellation final configuration reached on 27 November 2018 with Sentinel-3B placed in the same orbital plane as Sentinel-3A with a phase difference of 140°
  - ✓ OLCI revisit time better than three days (sun-glint free, daytime only)

S3A OLCI data availability

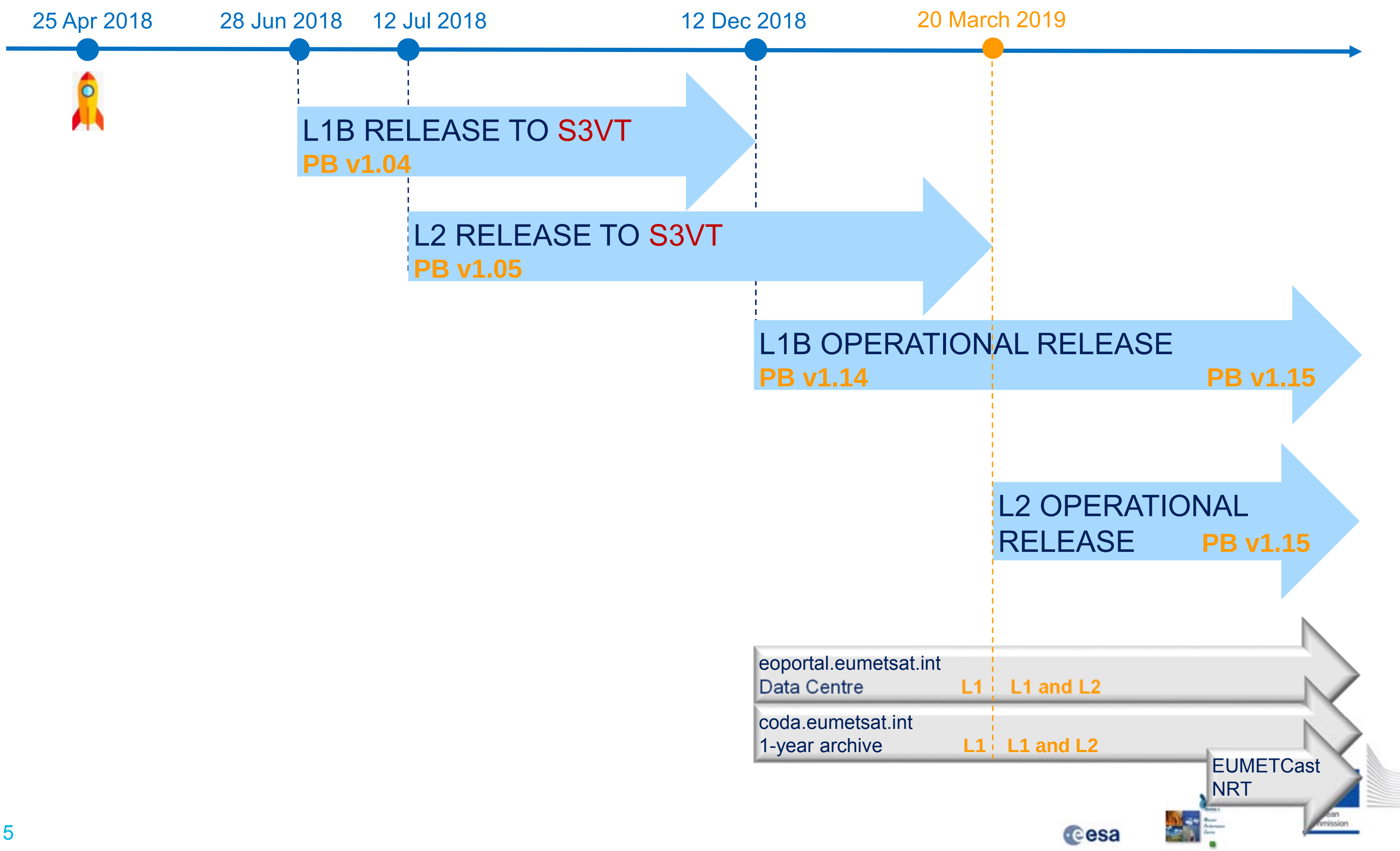


Main differences between PB v2.23 and PB v2.43

- Geometric calibration improvements
- No changes to L2 Ocean Colour processing, the only L2 changes are due to the L1B improvements

esa opernicus EUMETSAT

S3B OLCI data availability



esa opernicus EUMETSAT

Status of S3A products – water reflectance

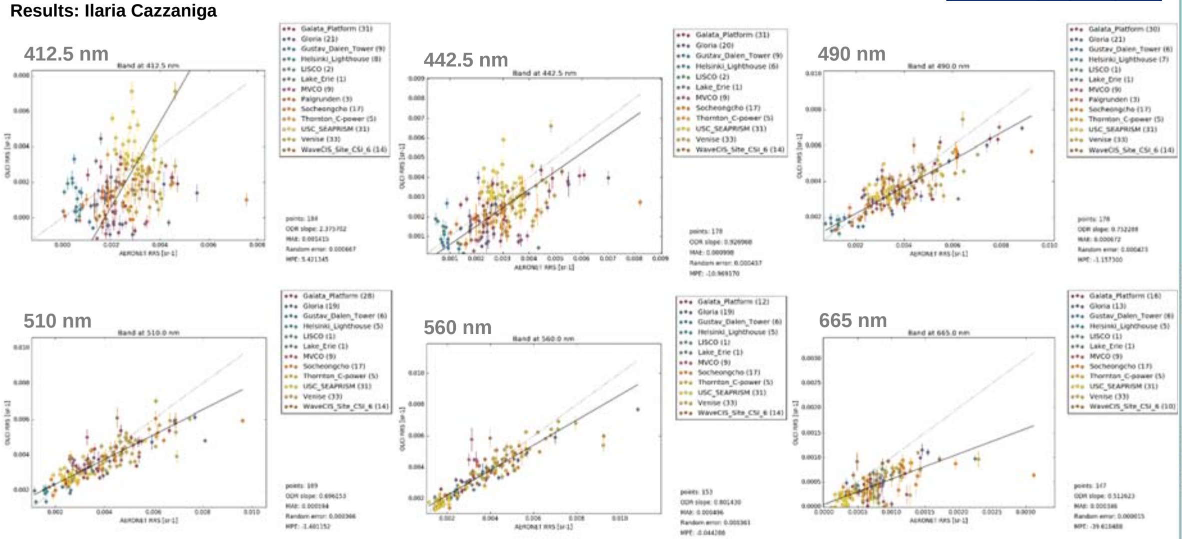
Water Reflectance partly meets the 5% S3 Mission Uncertainty Requirement at averaged global and temporal scales

- **Bands 490, 510, 560nm within 5% for all water types**
- **Bands 400, 412, 442nm within 5 - 10% depending on water type**
- **Other band uncertainties are higher and/or dependent on water type**
- **Product quality varies spatially and seasonally**

AERONET/Band	#no	MAE	MPE %
Rrs_412.5_nm	184	0.0014	5.42
Rrs_442.5_nm	178	0.0010	-10.97
Rrs_490.0_nm	178	0.0007	-1.16
Rrs_510.0_nm	169	0.0006	-1.40
Rrs_560.0_nm	153	0.0005	-0.04
Rrs_665.0_nm	147	0.0003	-39.61

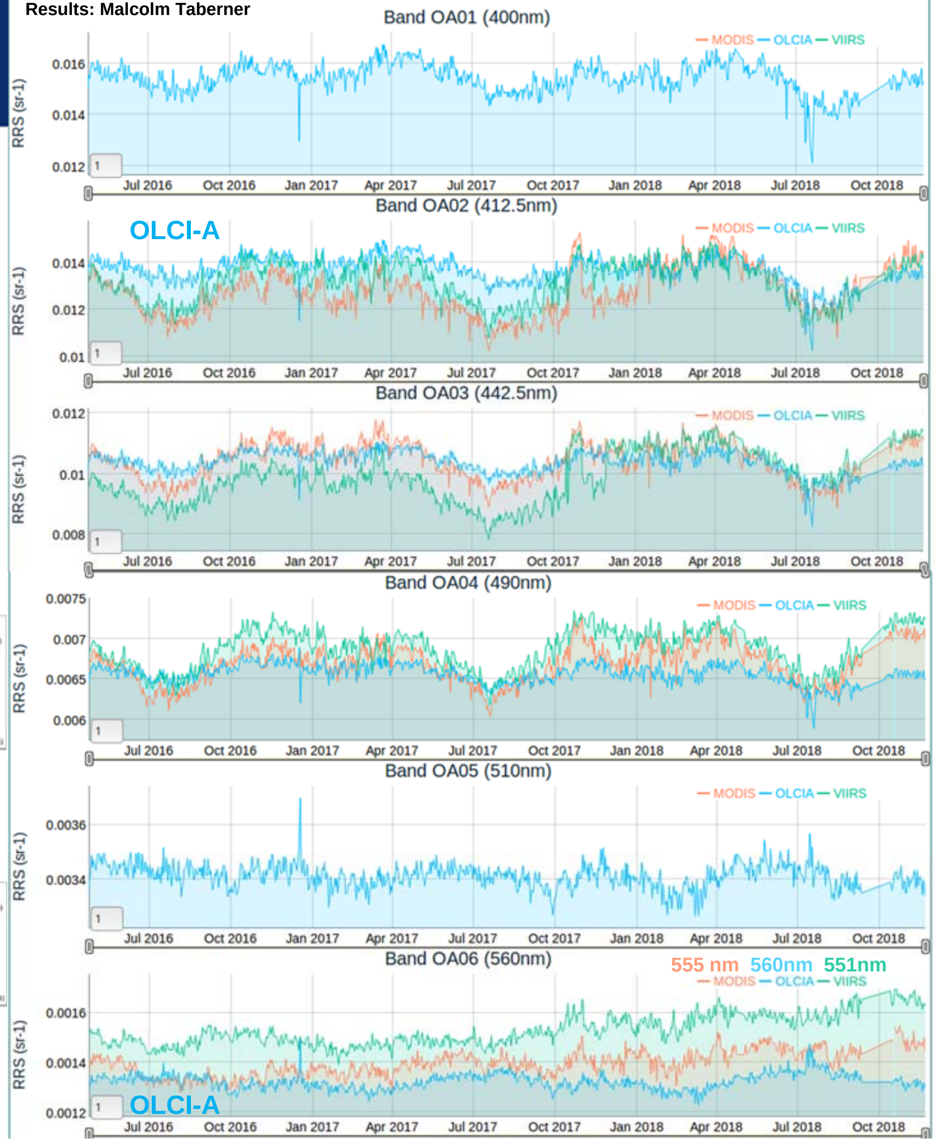
Validations with AERONET-OC
Acknowledgement: JRC, NASA, AERONET-OC PIs
Results: Ilaria Cazzaniga

Meso-/Eutrophic waters



Inter-comparisons with MODIS-A and VIIRS
Acknowledgement: NASA
Results: Malcolm Taberner

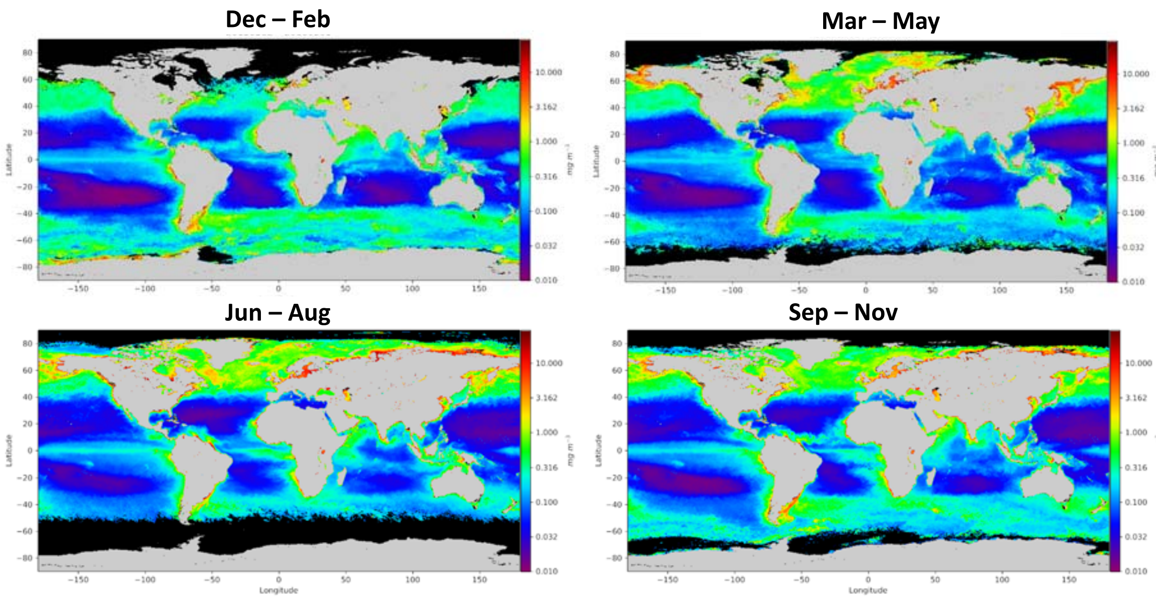
Oligotrophic waters



Status of S3A products – algal pigment concentrations

OC4ME Open Water algorithm (Case 1) partly meets S3 Mission Uncertainty Requirements at averaged global and temporal scales

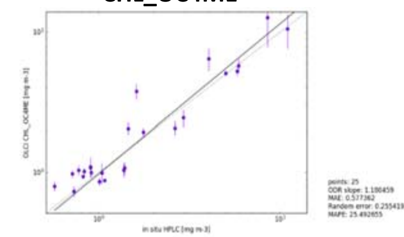
- Mesotrophic and eutrophic waters within 30%
- Oligotrophic waters underestimated by about 40%
- Product quality varies spatially and seasonally



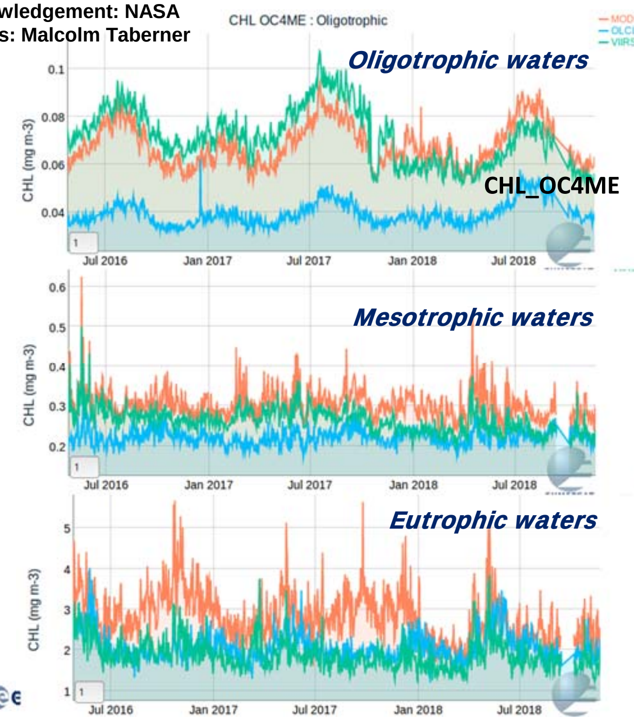
Acknowledgement: NASA, SeaBASS PIs
Results: Ilaria Cazzaniga

SeaBASS	#no	MAE	MAPE
CHL_OC4ME	25	0.577	25.49
CH_NN	27	2.290	75.82

CHL_OC4ME



Acknowledgement: NASA
Results: Malcolm Taberner



OLCI-A
MODISA
VIIRS

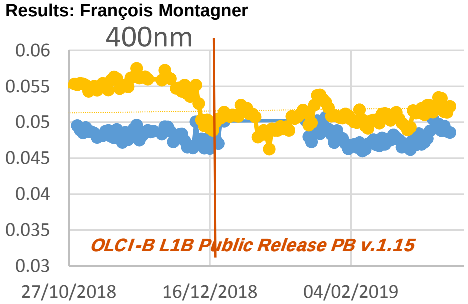
Status of S3B products – water reflectance

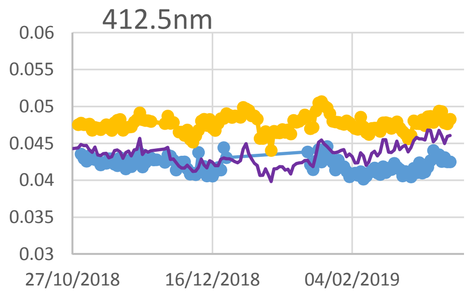
Water Reflectance does not meet the 5% S3 Mission Uncertainty Requirement – OC-SVC is not available

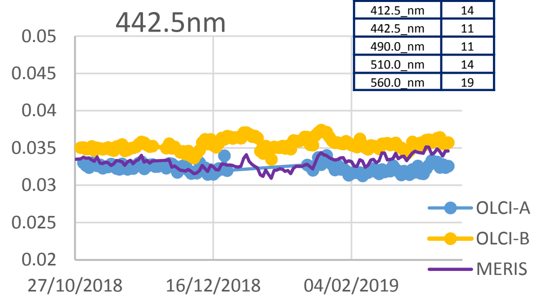
- **Blue/green bands have positive bias within 7 – 20% compared to OLCI-A in oligotrophic and mesotrophic waters**

Oligotrophic waters

Inter-comparisons OLCI-B with OLCI-A and MERIS Climatology
Acknowledgement: ESA, NASA for the Climatology
Results: François Montagner

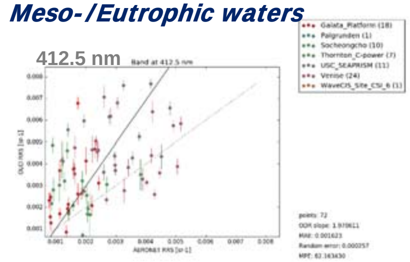


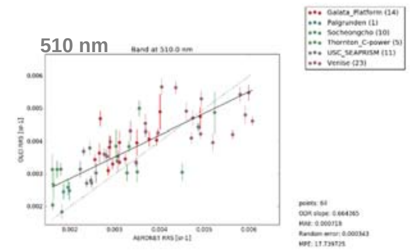




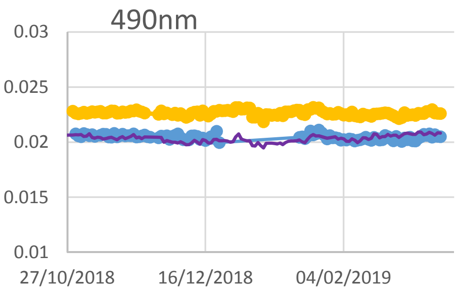
OLCI-B/OLCI-A	MPE %
400.0_nm	7
412.5_nm	14
442.5_nm	11
490.0_nm	11
510.0_nm	14
560.0_nm	19

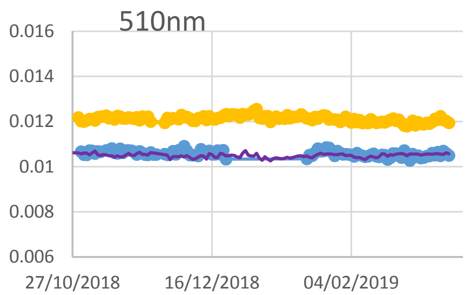
Meso-/Eutrophic waters

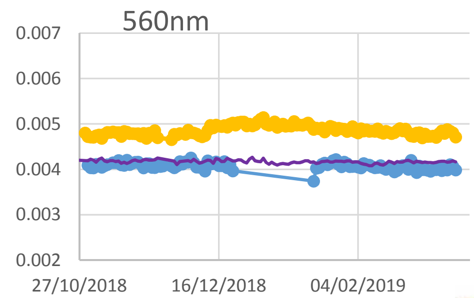


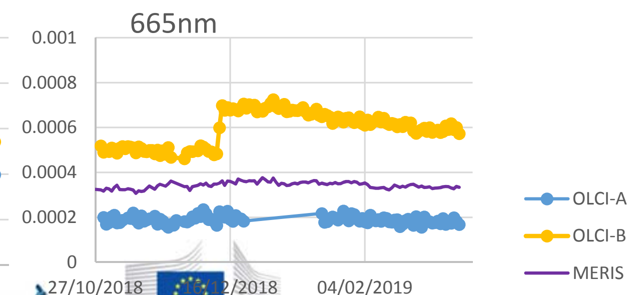


Validations v1.05+v.1.15 with AERONET-OC
Acknowledgement: JRC, NASA, AERONET-OC PIs
Results: Ilaria Cazzaniga





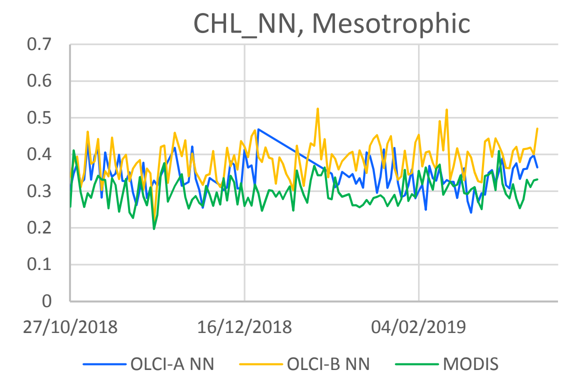


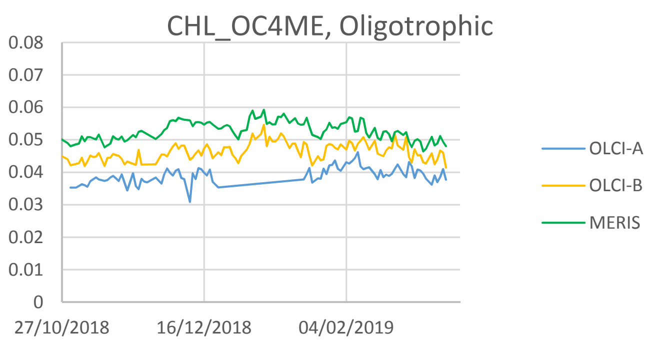


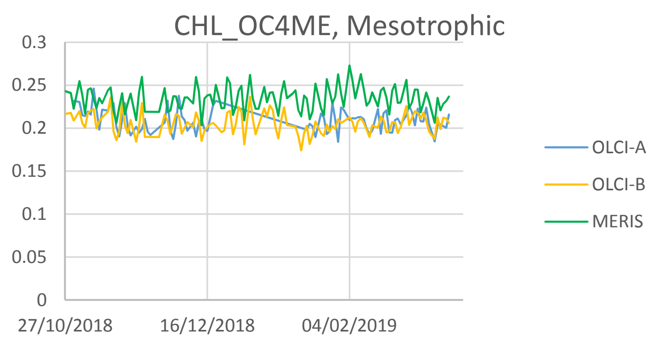
Status of S3B products – algal pigment concentrations

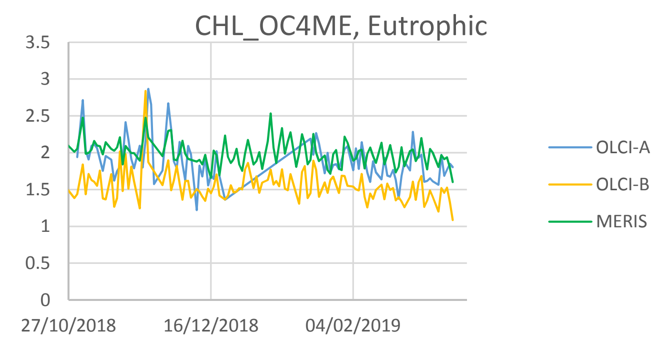
OC4ME Open Water algorithm (Case 1) may partly meets S3 Mission Uncertainty Requirements at averaged global and temporal scales

- **All water types may be within 30%**
- **However, no in situ ground-truth measurements are available to confirm**
- **Product quality varies spatially**









Inter-comparisons OLCI-B with OLCI-A, MERIS Climatology and MODIS
Acknowledgement: ESA, NASA
Results: François Montagner

See Poster#12 by Ilaria Cazzaniga for OLCI in situ validations

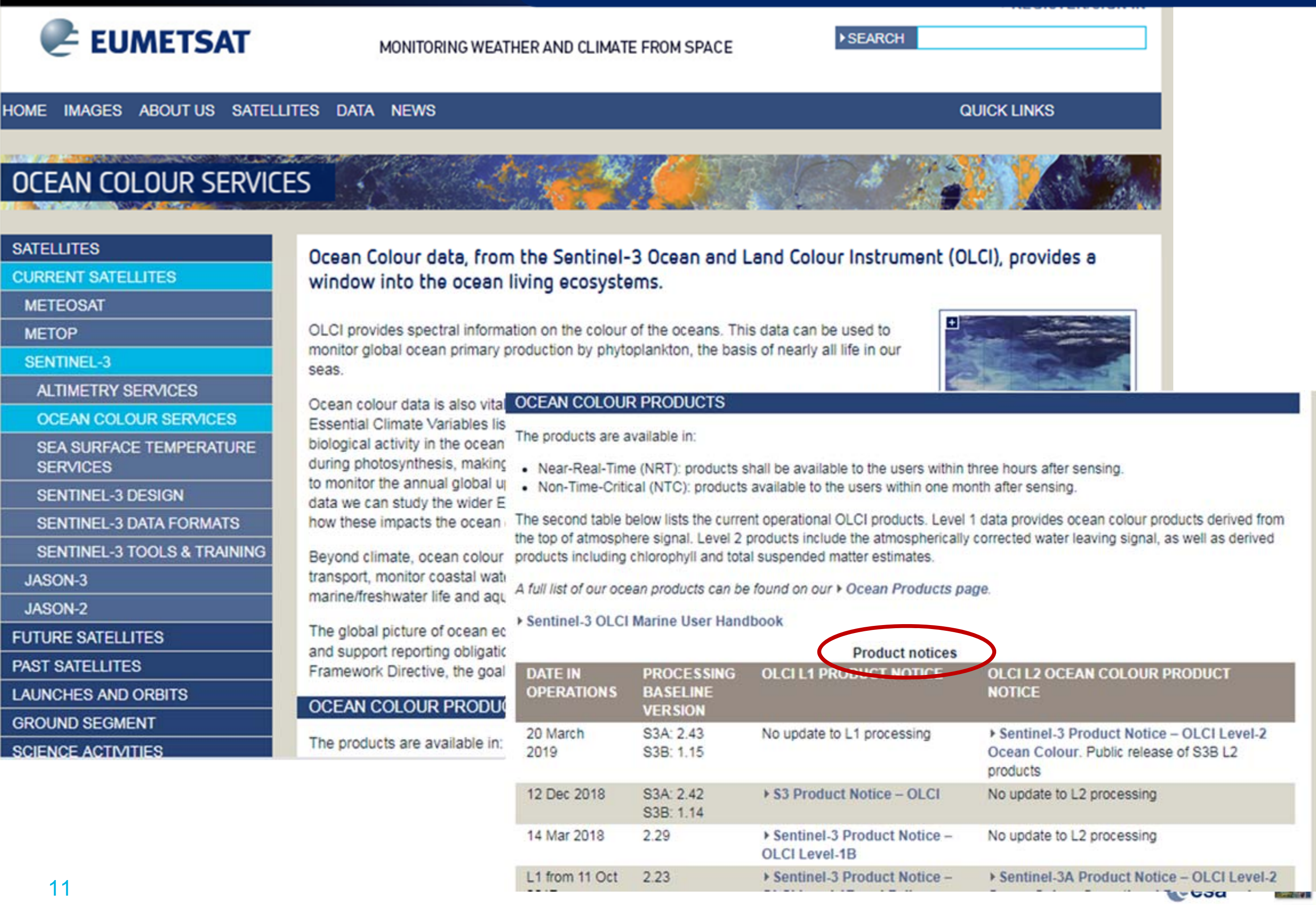
S3 OLCI L2 Ocean Colour product quality limitations

Limitation	Ongoing/planned activities
OLCI-B water reflectance non-compliance	Recomputation of OC-SVC gains in second half 2019 when more OC-SVC matchups and the complete annual cycle of OLCI-B measurements are available
OLCI-A remaining water reflectance non-compliances	*Idem*
CHL_OC4ME oligotrophic chlorophyll underestimation	Algorithm update under implementation
Residual flag limitations	Short term: algorithm update, under implementation Long term: revision of flags definition (QWG recommendation)
Residual angular/seasonal dependence varying with airmass	Investigations ongoing within the S3 Mission Performance Centre and QWG
'Salt and pepper' noise in Open Water products	Short term: algorithm update under implementation Medium term: algorithm improvement, ongoing study
Reduced quality in coastal and complex-water areas (e.g. CDOM dominated), recurring negative water reflectance	*Idem*
Complex Water NN algorithm (Case 2) limitations – variable quality, thresholds on product values	Algorithm update under implementation - altNN
Integrated water vapour biases	Medium term: algorithm improvement, ongoing study
L2 error products tentative (product_err)	Awaiting implementation of Level-1 error products, i.e. L1 per-pixel uncertainties
Consistent time series of products	Full-mission reprocessing of OLCI-A/B products planned in second half 2019

Resources

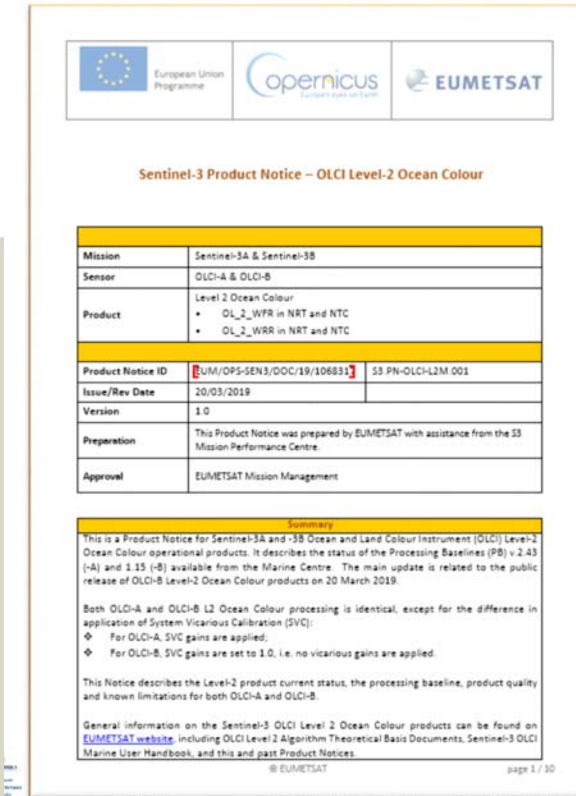
eumetsat.int

https://www.eumetsat.int/website/home/Satellites/CurrentSatellites/Sentinel3/OceanColourServices/index.html
http://forums.eumetsat.int/



DATE IN OPERATIONS	PROCESSING BASELINE VERSION	OLCI L1 PRODUCT NOTICE	OLCI L2 OCEAN COLOUR PRODUCT NOTICE
20 March 2019	S3A: 2.43 S3B: 1.15	No update to L1 processing	Sentinel-3 Product Notice – OLCI Level-2 Ocean Colour. Public release of S3B L2 products
12 Dec 2018	S3A: 2.42 S3B: 1.14	S3 Product Notice – OLCI	No update to L2 processing
14 Mar 2018	2.29	Sentinel-3 Product Notice – OLCI Level-1B	No update to L2 processing
L1 from 11 Oct	2.23	Sentinel-3 Product Notice –	Sentinel-3A Product Notice – OLCI Level-2

ops@eumetsat.int



European Union Programme | Copernicus | EUMETSAT

Sentinel-3 Product Notice – OLCI Level-2 Ocean Colour

Mission	Sentinel-3A & Sentinel-3B	
Sensor	OLCI-A & OLCI-B	
Product	Level 2 Ocean Colour • OL_2_WFR in NRT and NTC • OL_2_WRR in NRT and NTC	
Product Notice ID	EUM/OPS-SEN3/DOC/19/106831	S3.PN-OLCI-L2M.001
Issue/Rev Date	20/03/2019	
Version	1.0	
Preparation	This Product Notice was prepared by EUMETSAT with assistance from the S3 Mission Performance Centre.	
Approval	EUMETSAT Mission Management	

Summary

This is a Product Notice for Sentinel-3A and -3B Ocean and Land Colour Instrument (OLCI) Level-2 Ocean Colour operational products. It describes the status of the Processing Baselines (PB) v.2.43 (-A) and 1.15 (-B) available from the Marine Centre. The main update is related to the public release of OLCI-B Level-2 Ocean Colour products on 20 March 2019.

Both OLCI-A and OLCI-B L2 Ocean Colour processing is identical, except for the difference in application of System Vicarious Calibration (SVC):
- For OLCI-A, SVC gains are applied;
- For OLCI-B, SVC gains are set to 1.0, i.e. no vicarious gains are applied.

This Notice describes the Level-2 product current status, the processing baseline, product quality and known limitations for both OLCI-A and OLCI-B.

General information on the Sentinel-3 OLCI Level 2 Ocean Colour products can be found on EUMETSAT website, including OLCI Level 2 Algorithm Theoretical Basis Documents, Sentinel-3 OLCI Marine User Handbook, and this and past Product Notices.

© EUMETSAT page 1 / 10

- S3VT Annual meetings, active participation, excellent feedback
- S3VT-OC Monthly teleconferences
- S3VT meeting 7-9 May 2019 at ESA ESRIN in Frascati, Italy
  - Day-1 09:00 – 13:00 Plenary; 14:00 – 17:00 joint Optical session OLCI/SLSTR/calibration, 17:00 – 18:30 Posters
  - Day-2 09:00 – 17:00 parallel sessions (Ocean Colour), 17:00 – 18:30 Posters
  - Day-3 09:00 – 12:00 parallel sessions (Ocean Colour), 13:00 – 15:00 Plenary

IOCS recommendations – towards establishing Copernicus Ocean Colour System Vicarious Calibration

EUMETSAT has been cooperating with ESA, EC-JRC and international space agencies on activities towards establishing Copernicus OC-SVC capability

- **ESA organized an international Workshop on Vicarious Infrastructure in the frame of the FRM4SOC project (*report available* and final workshop *material*)**
- **EC-JRC published a series of peer-reviewed scientific papers and a JRC technical report (*report available*)**
- **EUMETSAT developed "*Requirements for Copernicus Ocean Colour Vicarious Calibration Infrastructure*" with inputs from an international expert review team**
- **EUMETSAT Copernicus initiated "*Preliminary Design of the Copernicus Ocean Colour Vicarious Calibration Project: Infrastructure, Project Planning and Costing*"**

Copernicus OC-SVC Roadmap
Step 1

Copernicus OC-SVC Roadmap
Step 2

Copernicus OC-SVC Roadmap

1. Requirements
2. Preliminary Design, Project Plan and Costing
3. Engineering Design, Technical Definition, Specifications
4. Development, Testing and Demonstration in the Field
5. Operations

Two parallel candidate OC-SVC Preliminary Designs: based on the optical system design of MOBY

Requirements for Copernicus Ocean Colour Vicarious Calibration Infrastructure

31st July 2017

Step-1
OC-SVC Requirements

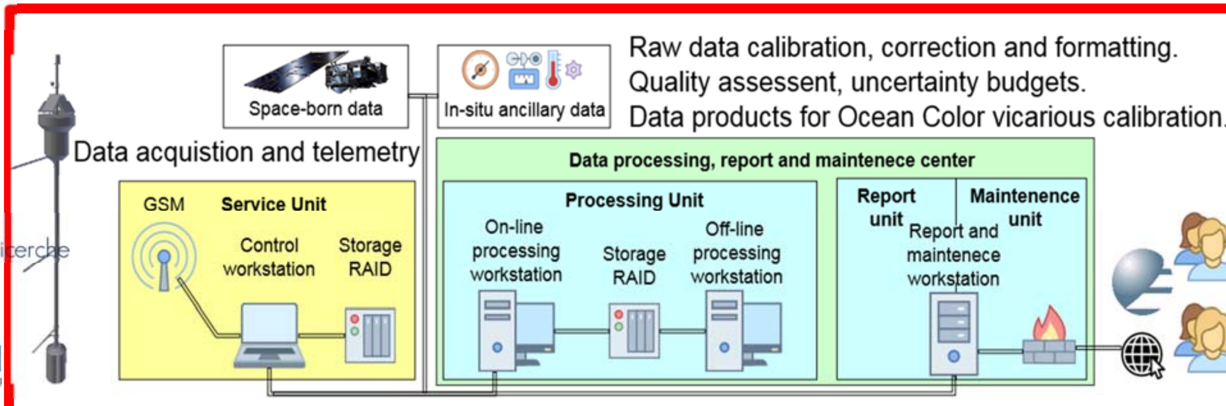
Step-2 Preliminary Design of the Copernicus OC-SVC infrastructure, planning and costing

FIELD SEGMENT

UNCERTAINTY BUDGET

GROUND SEGMENT

- In-water spectrophotometers
- MOBY-design optical system
- Ancillary instruments and HW
- Independent buoys design
- Site selection and characterization



Consiglio Nazionale delle Ricerche

sol√o

Æquora consulting

ENEA

European Commission Copernicus EUMETSAT

Two parallel candidate OC-SVC Preliminary Designs: based on the field design of BOUSSOLE


Requirements for Copernicus
Ocean Colour Vicarious Calibration
Infrastructure

31st July 2017

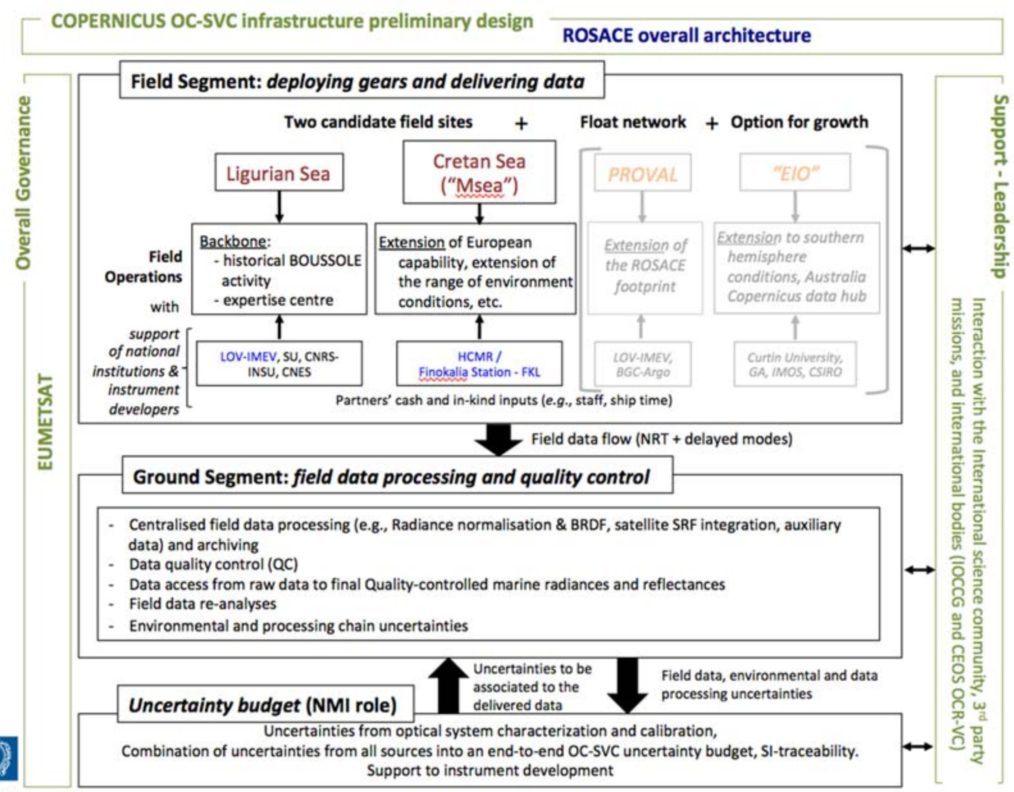
Step-1
OC-SVC Requirements

Step-2 Preliminary Design of the Copernicus OC-SVC infrastructure, planning and costing

FIELD SEGMENT

UNCERTAINTY BUDGET

GROUND SEGMENT



IOCS recommendations
advances in Atmospheric Correction, NIR modelling

OC-BPC

Ocean Colour Bright Pixel Correction

Objective: develop an ***improved correction for non-negligible water reflectance in the NIR*** **for OLCI**

Schedule: **June 2018 – June 2019**

solvo

HYGEOS

Helmholtz-Zentrum Geesthacht
Centre for Materials and Coastal Research

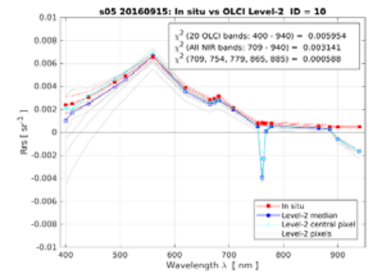
Review of OC-BPC approaches to facilitate the NIR-based clear water Atmospheric Correction

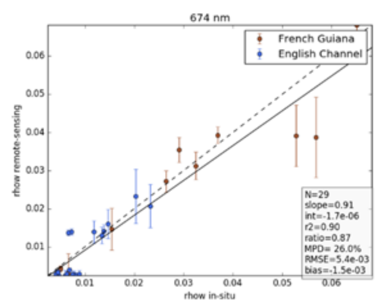
- Marine modelling in the NIR: IOPs and BRDF reflectance model
- Numerical inversion: spectral optimization method with configurable bands
- Uncertainty formalism: per-pixel radiometric and model uncertainties
- Analysis of ambiguities in the water/atmosphere decoupling
- Modular processing code

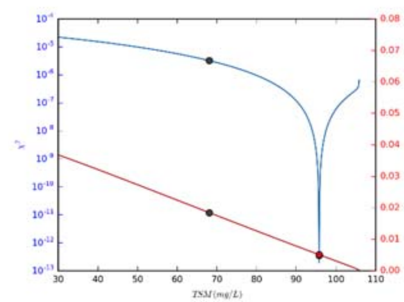
Integration of community's recent advancements in Atmospheric Correction over complex waters

Validation and analysis of the improvements using in-situ measurements, selected scenes and time series

International Expert Team is gratefully acknowledged for exceptionally valuable support to this study







See Breakout workshop #9 and the next S3VT meeting 7-9 May 2019

European Commission

Copernicus

EUMETSAT

IOCS recommendations
advances in aerosol Atmospheric Correction

SACSO

Spectral matching Atmospheric Correction for Sentinel Ocean colour measurements

HYGEOS

solvo

Objective: develop an *improved aerosol atmospheric correction*, with application to OLCI and other sensors

Schedule: March 2019 - August 2020

Spectral matching approach based on Polymer

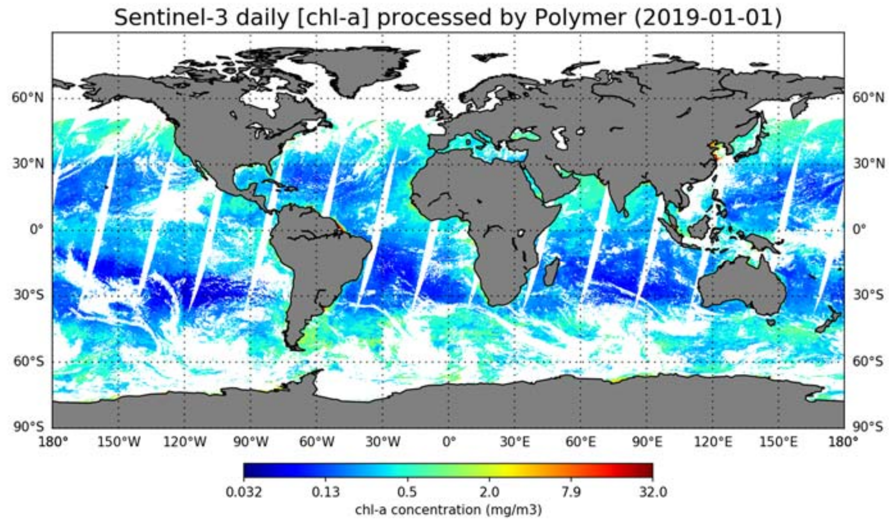
- Generic and accurate in oceanic and coastal waters
- Using a wide range of spectral bands for atmospheric correction allows for an enhanced precision, especially in the shortest wavelengths
- Robust to aerosols (including absorbing ones) and other atmospheric and surface effects: sun glint, thin clouds, adjacency effects

Scientific tests and developments to improve and consolidate the algorithm

- Review the atmospheric and surface model. In particular, account for the aerosol transmittance
- Review the water reflectance model
- Review the optimization scheme: improve algorithm stability over oligotrophic waters
- Develop an uncertainty propagation scheme
- Optimize the choice of spectral bands

Validation and analysis of the improvements

- Using simulated and in-situ data
- Integration of the aerosol AC module in a multi-mission Ocean Colour prototype



European Commission

Copernicus

EUMETSAT

IOCS recommendations
advances in IOP inversion in oceanic and inland waters

IOP

IOP inversion in natural oceanic and inland surface waters

A two steps approach selected:

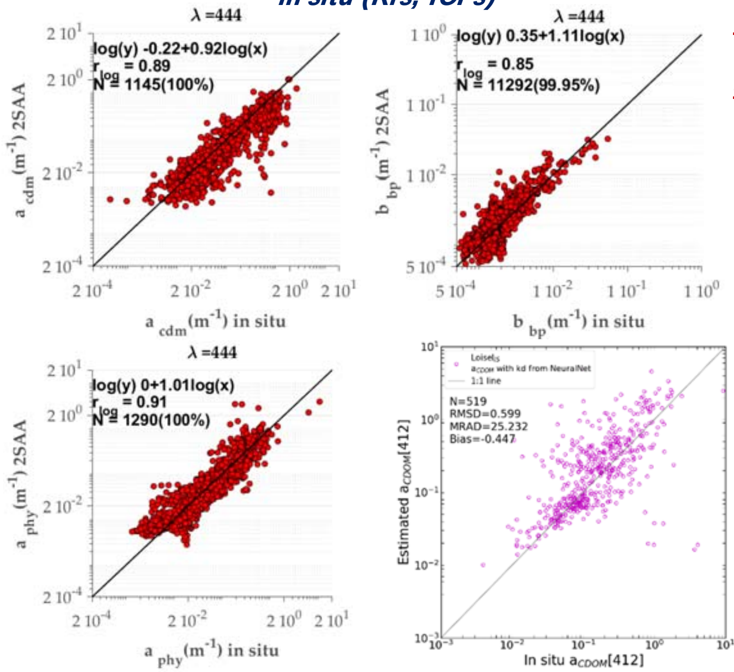
- Different algorithms were tested to estimate a_{phy}, a_{cdm}, b_{bp}, and a_{cdom}
- Algorithm is coupled with a water type classification

Algorithm has been validated over open, coastal, and inland waters based on in situ R_{rs} and IOPs measurements, as well as using match-up data points

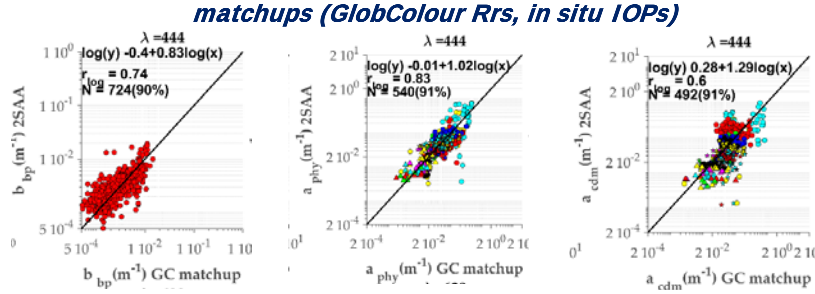
Uncertainties are provided for each IOP based on a class based approach

International Expert Team is gratefully acknowledged for exceptionally valuable support to this study

in situ (Rrs, IOPs)



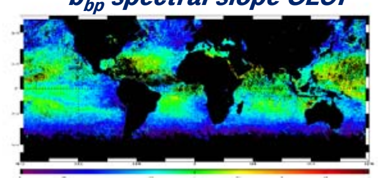
matchups (GlobColour Rrs, in situ IOPs)



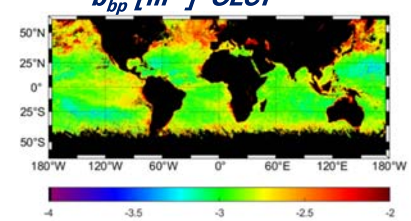
Objective: develop IOPs for OLCI

Schedule: Jan 2018 - May 2019

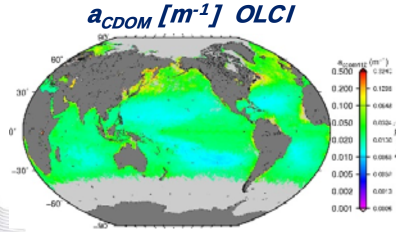
b_{bp} spectral slope OLCI



b_{bp} [m^{-1}] OLCI



a_{CDOM} [m^{-1}] OLCI



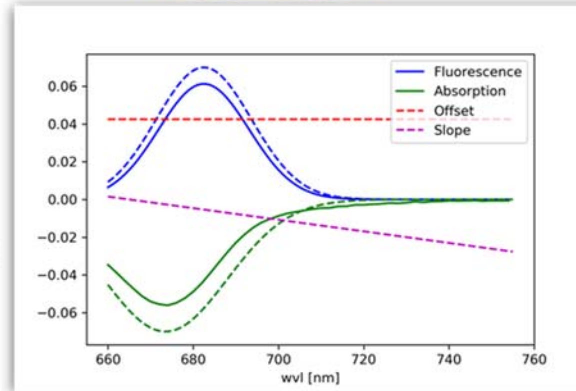
Copernicus EUMETSAT

IOCS recommendations
advances in phytoplankton fluorescence retrievals

Fluorescence
Phytoplankton physiology

Spectral Earth GmbH

$$\rho_{toa}(\lambda) = O + S * \lambda + A * e^{(\lambda - 673.5nm)^2 / w_A} + F * e^{(\lambda - 682nm)^2 / w_F}$$



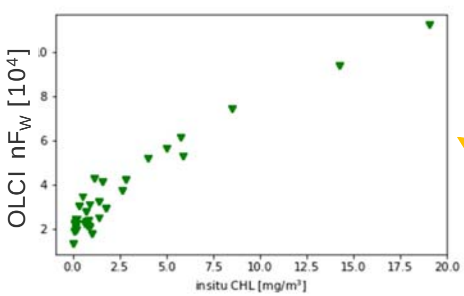
Review of user requirements, state-of-the-art and OLCI capabilities for fluorescence detection

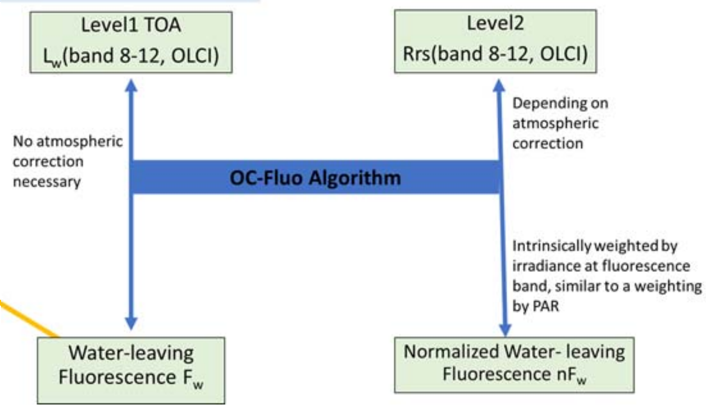
Two parallel developments of fluorescence from the L1 TOA radiance and from L2 water reflectance

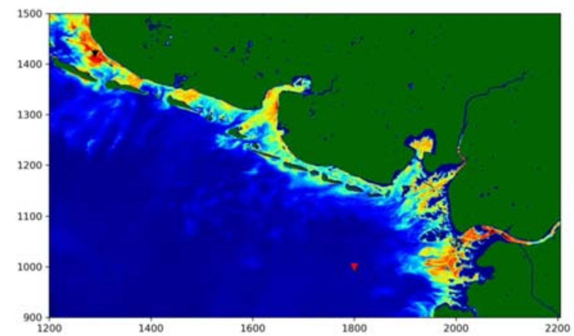
Validation and analysis of product quality

Objective: develop fluorescence product for OLCI

Schedule: Sep 2018 – Sep 2019

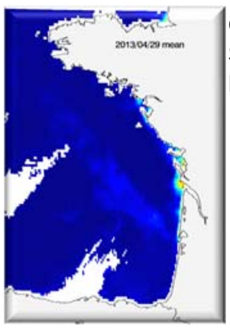






IOCS recommendations
benefits of geostationary Ocean Colour capabilities

❶ Significant improvement in coverage



GEO
SEVIRI
MSG3

MODIS
Aqua

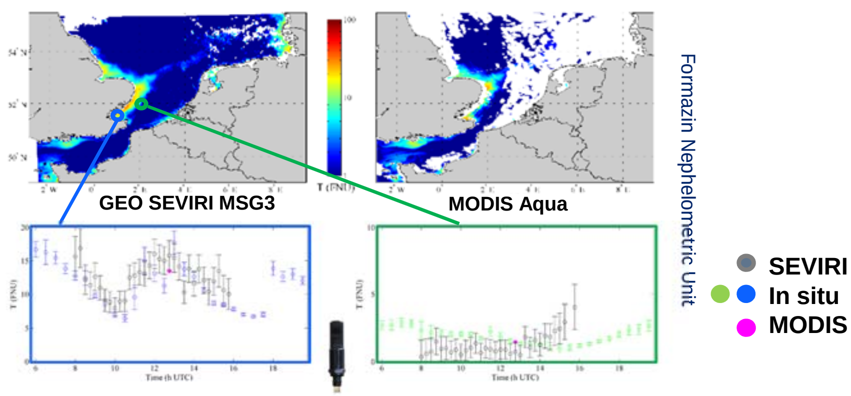
increased chance of obtaining cloud-free data compared to standard polar observations, data free of gaps between orbits

Bay of Biscay

daily coverage from a geostationary and a polar mission

showing a coccolithophore bloom: major process for long-term carbon burial in the oceans

❷ Monitoring of dynamic processes



tidal dynamics, eddies, fronts, sediment transport, coastal erosion, river plumes, natural and anthropogenic disasters

[Neukermans et al, 2012; Neukermans, 2012]

References

- Pioneering Geostationary Ocean Colour Imager (GOCI) from KIOST, since 2010
- International Ocean Colour Science meeting reports, http://iocs.ioccg.org/, 2013, 2015
- Copernicus Marine Environment Monitoring Service (CMEMS) requirements for the evolution of the Copernicus Satellite Component, 2017
- GMES-Partnership for User Requirements Evaluation, EC GMES-PURE, 2015
- International Ocean Colour Coordinating Group, IOCCG report #12, edited by Antoine, 2012

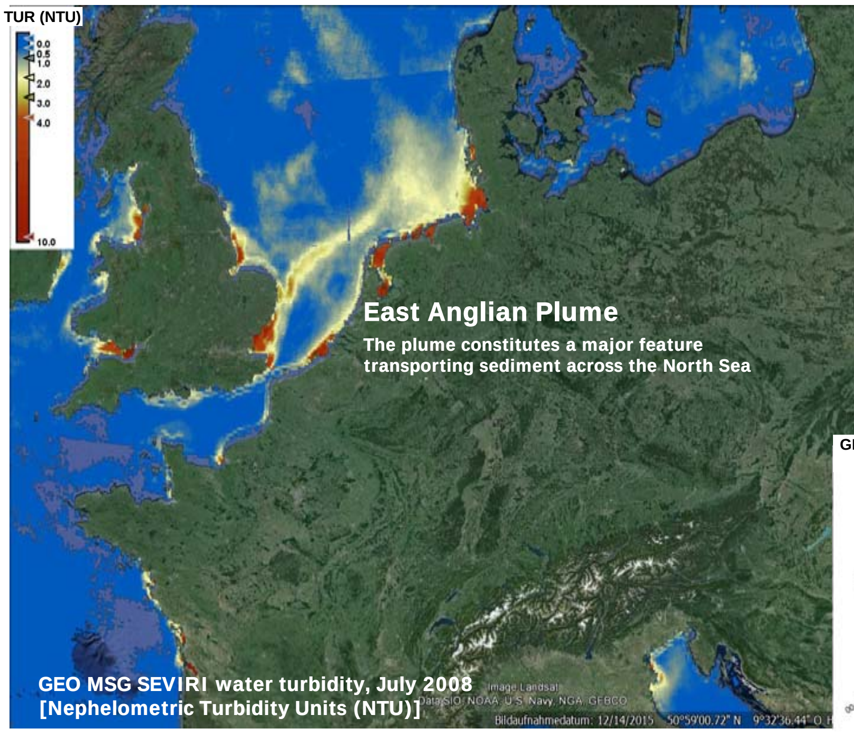
museum
Brockmann Consult GmbH
HYGEOS

EUMETSAT

Demonstration of GEO MSG water turbidity monitoring and MTG feasibility for chlorophyll retrievals

Completed GEO activities **User Requirements**
MSG SEVIRI prototype processor and validation

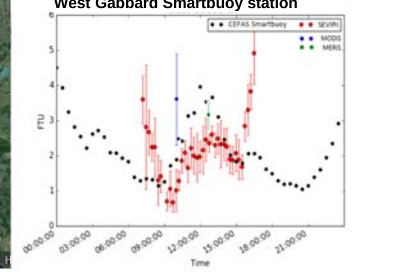
Development endorsed by Copernicus Marine Environment Monitoring Service



GEO MSG SEVIRI water turbidity, July 2008
[Nephelometric Turbidity Units (NTU)]

User Applications	Parameter	Best Spatial Resolution	Temporal Resolution	Accuracy
Coastal water quality (EU MSFD)	TUR, SPM, SD	300m-1km	1h – 10y+	threshold
Water quality of European lakes (EU WFD)	TUR, SD, XCYA	300m-1km	1h – 10y+	threshold
Coastal water quality - Africa	TUR, SD, XHAB	~1km	1h – 10y+, NRT	scientifically sound
Water quality of African lakes	TUR, SD, XCYA	300m-1km	1h – 10y+	scientifically sound
Sediment transport	TUR, SPM	10m-1km	1h – 10y+	absolute
Ecosystem modelling (eutrophication)	KdPAR/ZE, SPM	1-10km	1h – 10y+, some NRT	uncertainty per pixel
Offshore diving operations	TUR (HVIS)	1-100m?	10m – 6h, NRT	scientifically sound
Carbon burial by coccolithophores	COCCO	~10km?	1h – 10y+	unknown
Support for OC validation	Rrs	300m-1km	5m – 10y+	absolute

GEO MSG SEVIRI water turbidity validation
West Gabbard Smartbuoy station



GEO MSG SEVIRI water turbidity
July 2008, Lake Victoria, Africa

museum
Brockmann Consult GmbH
HYGEOS

Upcoming development **Multi-year MSG SEVIRI water turbidity time series**
MTG FCI feasibility study of additional OC products, like chlorophyll, a_{ph440}, a_{cdm440}, $K_{d\lambda}$

EUMETSAT

EUMETSAT

- ✓ Sentinel-3A and -3B OLCI constellation is now operational!
- ✓ OLCI product improvements ongoing
- ✓ Copernicus OC-SVC roadmap activities in step 2 ‘preliminary design’
- ✓ Scientific studies in progress on algorithm evolution and new products
- ✓ Activities follow IOCS recommendations and harness international expertise